UDC 621.396.633.029.62
621.391.827.

BBC

RESEARCH DEPARTMENT REPORT

The susceptibility of portable Band II f.m. receivers to interference by services operating in adjacent frequency bands

No. 1969/9

Research Department, Engineering Division
THE BRITISH BROADCASTING CORPORATION

RESEARCH DEPARTMENT

THE SUSCEPTIBILITY OF PORTABLE BAND II F.M. RECEIVERS TO INTERFERENCE BY SERVICES OPERATING IN ADJACENT FREQUENCY BANDS

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May 1969

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THE SUSCEPTIBILITY OF PORTABLE BAND II F.M. RECEIVERS TO INTERFERENCE BY SERVICES OPERATING IN ADJACENT FREQUENCY BANDS

SUMMARY

Nine portable receivers, designed for f.m. reception and retailing at prices ranging from under £10 to over £25, were tested for their susceptibility to interference by an amplitude-modulated signal whose carrier frequency differs from that of the wanted signal by between 300 kHz and 3·5 MHz. The tests were repeated on some of the receivers for interference by frequency-modulated signals, both narrow-band (± 5 kHz deviation) and wide-band (± 75 kHz deviation).

At 1·5 MHz channel spacing an a.m. interfering signal typically about 40 dB above the wanted signal gives just perceptible interference, but there are wide variations from receiver to receiver. The tolerable level of interfering signal reduces rapidly at smaller frequency separations but improves only slightly at greater spacings. A 10 to 20 dB higher level of interfering signal is tolerable if the interfering signal employs narrow-band f.m.

1. INTRODUCTION

The part of the v.h.f. broadcast band (Band II) at present occupied by the BBC sound services and local broadcasting stations is confined, in most areas, to the range 88 to 95 MHz. The bands immediately above and below this are occupied by Home Office mobile services and base stations of other mobile services, such as taxis and plant-maintenance organizations. Frequency assignments of these services are at present 350 kHz or more away from the carrier frequencies of Band II broadcast stations in the same area but it is possible that closer spacings may be used in the future. Existing installations use one of three types of modulation:

(i) a.m.
(ii) f.m. with a peak deviation of ± 5 kHz
(iii) f.m. with a peak deviation of ± 2·5 kHz

It is understood that licences issued for the operation of new services in the Private Land Mobile Service band (below 88 MHz) will be for operation either with a.m. or with ± 2·5 kHz f.m.[1] but existing services using ± 5 kHz f.m. will be allowed to continue. The frequency band between 95 and 97·6 MHz contains at present both broadcasting and Home Office mobile services but present plans are that within a few years it will be used only for broadcasting. The frequency band above this will continue to be used for Home Office mobile services; it is understood that the modulation systems used at present are a.m. and ± 5 kHz deviation f.m. with no likelihood of changing to ± 2·5 kHz in the near future.

Tests were made on the susceptibility of a number of receivers to interference from services of this type, both for amplitude modulation and for frequency modulation with a peak deviation of ± 5 kHz. A few additional tests were made to assess the effects of f.m. with a peak deviation of ± 2·5 kHz. For all of these tests, the interfering signal was modulated by speech.

The opportunity was also taken to extend to cheaper receivers measurements of interference from another f.m. broadcast transmission, since previous measurements of this type had been confined to more expensive receivers.

The term 'interference rejection ratio' will be used to mean the ratio of the strength of the just-perceptible interfering signal to the strength of the wanted signal. The amount by which the interfering carrier frequency exceeds the wanted carrier frequency will be denoted by Δf.

2. THE TEST CONDITIONS

The modulating signals for both the wanted and the interfering signal channels were obtained from high-grade two-track magnetic tape equipment with negligible cross-talk between the channels.

For all of the tests the wanted modulation was a news bulletin read by a male announcer. The modulation channel included a standard 50 μs pre-emphasis network and the a.f. gain was adjusted so that modulation at maximum audio signal level by 400 Hz tone gave a peak deviation of −4 dB relative to ± 75 kHz, in accordance with current British practice in f.m. broadcasting.

For the tests using an a.m. or a narrow-band f.m. interfering signal the interfering modulation was a different part of the same news bulletin. Pre-emphasis was not used, and the modulation channel included a limiter-compressor (BBC type AM6/3A) adjusted to give 10 dB of compression and an a.f. peak clipper to remove any over-modulation transients not removed by the limiter.

For tests simulating an f.m. broadcast interfering signal the interfering modulation was a recording of 'Music While You Work.' The interfering modulation channel was then a replica of that used for the wanted signal.

The wanted and interfering r.f. signals after control of the levels, were combined in a hybrid network. If the receiver had an aerial socket it was used for injection of the signal; if not, the signal was applied between the base of the (retracted) rod aerial and a suitable earth point of the chassis. Unless otherwise stated, the wanted signal level was 100 μV r.m.s. open-circuit voltage with a source impedance of 75Ω.

In all cases the receiver was tuned to the wanted signal in the absence of interference and the level of the interfering signal was then adjusted so that the interference was 'just perceptible,' (Grade 2 on the EBU 6-point Impairment Scale), i.e. so that its presence was detectable at that level but not at the next lower available level, normally controlled by a 2 dB step attenuator. This level was somewhat imprecise because it depended both on the background noise level and on the accuracy of tuning of the receiver. Each test was therefore performed several times, (i.e. the interference was switched off, the receiver tuned and the level of the interfering signal again adjusted to the 'just perceptible' level) and the mean of the results was taken as the representative figure.

For convenience, the receivers are referred to in the text of this report as Receiver A, Receiver B, . . . Receiver I. Their approximate sizes and prices are given in the Appendix.

3. TESTS WITH AN AMPLITUDE-MODULATED INTERFERING SIGNAL

3.1. Tests Using Speech Modulation

Nine portable receivers, with provision for f.m. reception and retailing at prices ranging from under £10 to over £25, were tested for their susceptibility to interference by a signal that was 100% amplitude-modulated by speech. For each receiver and at various offset frequencies the level of the interfering signal was adjusted to give 'just perceptible' impairment (Grade 2 on the EBU impairment scale) of the wanted signal, first with the wanted signal at normal level (100 μV) and then with the wanted signal at +6 dB and −6 dB relative to this level.

The interference rejection ratio was the same for zero and 10 dB of compression in the limiter, the only difference being the proportion of the time for which the interference reached the just-perceptible level.

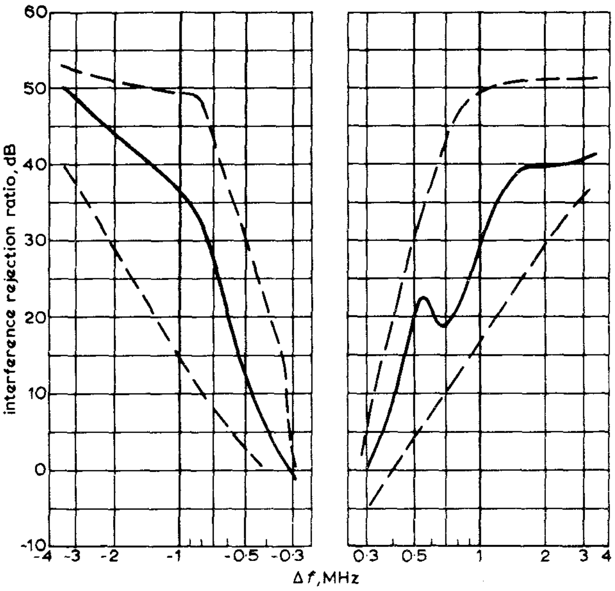


Fig. 1 - Interference rejection ratio; a.m. interfering signal

Median value
Range of values for nine receivers

The interference-rejection ratios of the nine receivers, averaged over the three input-signal levels, are shown in Table 1; the range of values and the median value are plotted against Δf in Fig. 1. The kink in the median-value curve between Δf = 0·5 MHz and Δf = 1·0 MHz is a feature which is common to many of the sets of measurements, the frequency at which the kink occurs depending on the frequency of the wanted carrier. The effect appears to be due to the presence of an additional interfering signal which is picked up by the aerial; the offending signal was not identified in these tests, but a definite identification was made in the tests described in Section 4.

For a few receivers operating under some conditions (particularly for the smaller values of Δf when the level of the just-perceptible interfering signal is less than 20 dB above the level of the wanted signal) the interference-rejection *ratio* remains nearly constant as the wanted signal level changes ± 6 dB. In general, though, the level of the just-perceptible interfering signal does not rise in proportion to the level of the wanted signal. In fact, under conditions of high interference-rejection ratio, when the interfering signal is not perceptible until it is approximately 40 dB above the wanted signal, the absolute level of a just-perceptible interfering signal tends to be constant or even fall slightly as the wanted signal level increases. This implies that the interference rejection ratio can often be improved if both input signal levels are lowered (e.g. partial retraction of the rod aerial may be beneficial in cases of interference).

TABLE 1

Interference Rejection Ratio when Interfering Signal is Amplitude-Modulated. (Mean of Results for Wanted Signal Levels of 50, 100 and 200 μV)

Δf, MHz	Interference Rejection Ratio, dB for Receivers:								
	A	B	C	D	E	F	G	H	I
−3·5	51	49	53	50	38	52	48	49	50
−3·0	53	48	46	49	41	52	46	46	50
−2·5	52	49	39	48	31	46	48	46	44
−2·0	39	43	32	48	28	47	48	43	28
−1·5	30	45	26	49	22	50	45	41	36
−1·0	23	46	14	47	14	41	42	38	29
−0·8	20	49		41	9	32	36	36	26
−0·6		28		37	1	15	33	18	
−0·5	6	24		30		10	29	14	16
−0·45	5	21		31		7	26	12	8
−0·4	1	13		28		4	20	6	8
−0·35	0	8		22		2	16	3	5
−0·3	0	−4		21		−10	8	−1	−1
+0·3	−3	+4		−6		+10	−5	+2	+9
0·35	+2	13		+4		13	0	11	14
0·4	10	18	4	10		19	3	12	21
0·45	7	27	3	13		24	8	12	22
0·5	5	25		28		27	23	16	25
0·6	8	40		28	8	28	9	6	32
0·8	15	48	13	32	14	38	20	15	40
1·0	31	50	15	32	17	48	21	24	37
1·5	40	48	26	43	32	51	34	40	41
2·0	39	47	36	40	40	47	33	41	39
2·5	51	49	39	40	39	48	32	37	43
3·0	51	48	41	41	41	43	31	41	44
3·5	51	45	39	43	39	51	39	41	44

Values left blank not measured or unreliable because of outside interference.

3.2. Subsidiary Tests

Two subsidiary tests were made on the receivers to confirm possible mechanisms of the interference process. First, the wanted carrier was frequency-modulated by speech, as in the main tests, and the receiver tuned. The wanted carrier was then simultaneously amplitude-modulated by 1 kHz tone and the depth of amplitude modulation noted at which the effect heard in the output from the receiver was just perceptible. The results varied from 3% for the poor receivers to 25% for the best receivers, showing that they would all be sensitive to amplitude modulation of the wanted signal produced by non-linearity in the early stages of the receiver.

Secondly, Receiver D was fed, at the standard 100 μV signal level, from a signal generator whose frequency was 0·6 MHz above the tuning frequency of the receiver (approximately 100 MHz). A special receiver, with an oscilloscope display of its discriminator output, was loosely coupled to the oscillator of Receiver D and correctly tuned to it. The signal generator was 40% amplitude-modulated by 1 kHz tone and its level raised. This produced in the oscillator of Receiver D both a shift of mean carrier frequency and frequency modulation at 1 kHz. The peak deviation of this induced f.m. was read off the oscilloscope and the values are shown in Table 2. It will be seen that the effect is very non-linear, which was confirmed by listening to the output of the special receiver.

It is clear that frequency modulation of the local oscillator of the receiver by the interfering signal can be a significant factor in the types of interference considered in this Section.

TABLE 2

Frequency Modulation of the Oscillator of Receiver D by a 40% Amplitude-Modulated Input Signal
$\Delta f = +0{\cdot}6$ MHz

Level of input signal, dB above 100 μV	Peak-to-peak deviation of receiver oscillator frequency kHz
+40	3
+46	8
+50	20

4. TESTS WITH A NARROW-BAND FREQUENCY-MODULATED INTERFERING SIGNAL

4.1. The Method of Testing the Receivers

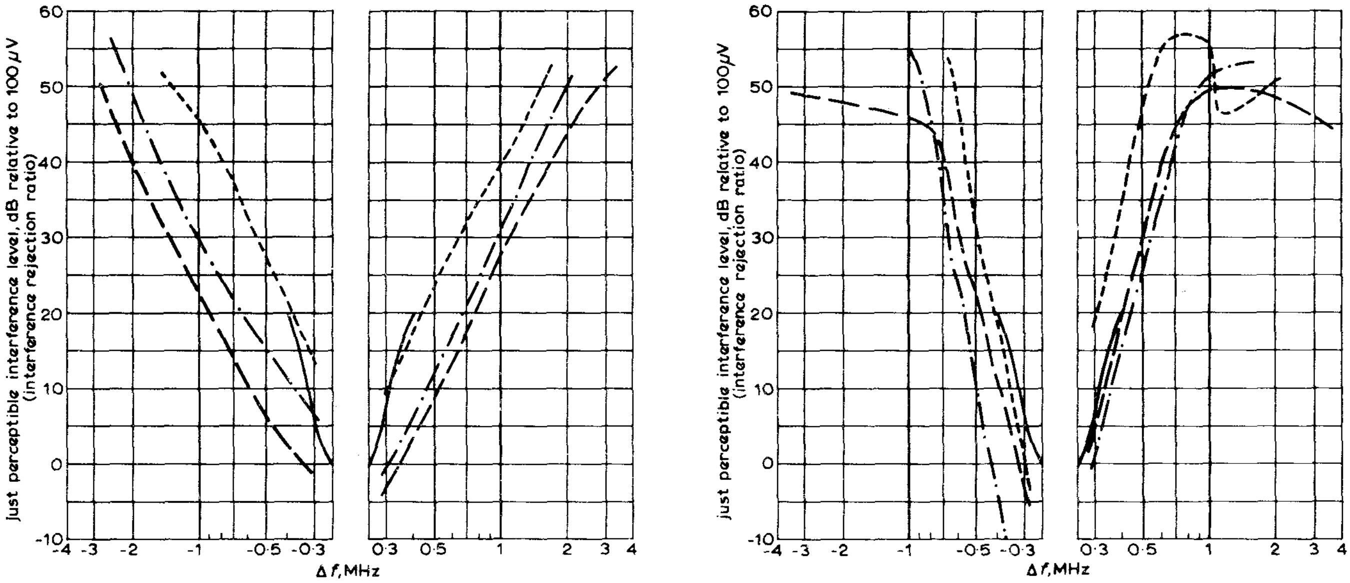
Tests of the required interference-rejection ratio were performed on four receivers, A to D, that were chosen as being representative of the nine available. The amplitude of the wanted carrier was kept constant at 100μV, the frequency was approximately 96 MHz and the carrier was frequency-modulated by speech as for the first test.

For tests on the effects of narrow-band f.m. the interfering modulation was compressed speech, the peak level being adjusted to produce full deviation (± 2·5 or ± 5 kHz according to which system was being tested).

The receiver was tuned to the wanted signal in the absence of interference and the interfering signal level was then raised until its presence was just perceptible.

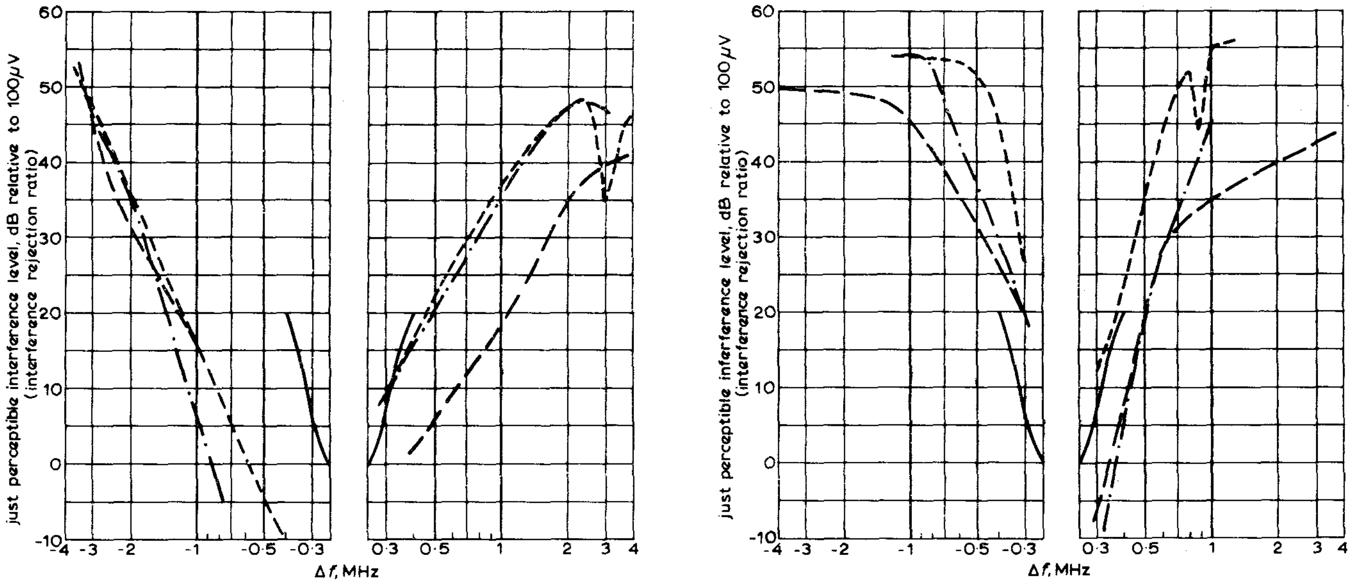
4.2. Results

Preliminary measurements were made on all four receivers for a few values of Δf, for both ± 5 and ± 2·5 kHz peak deviation. The interference first becomes perceptible as an increase of receiver noise



Receiver A

Receiver B



Receiver C

Receiver D

Fig. 2 - Interference rejection ratio; comparison between modulation systems

-------- f.m. ±5 kHz deviation. Speech modulation —·— f.m. Standard pre-emphasis and deviation. Light music modulation

— — — a.m. 100% modulation by speech ——— CCIR 'Necessary Protection Ratio' level, the carrier level for just-perceptible interference being independent of whether the modulation deviation is 5 kHz or 2·5 kHz. Greater amplitudes of the interfering carrier have different effects on the selected receivers. In the two better-quality receivers the modulation with 5 kHz deviation became audible at an interfering carrier level approximately 2 dB higher than that for a just-perceptible noise change, and for 2·5 kHz deviation the modulation became just perceptible at a carrier level about 4 dB higher still, without significant distortion of the wanted modulation. In the worst receiver the interfering modulation could not be distinguished as the carrier level was raised but there was a progressive, serious distortion of the wanted modulation. The performance of the fourth receiver lay between these two types, combining audible interference modulation with distortion of the wanted modulation. The tests of the four receivers were completed using 5 kHz deviation of the interfering carrier and the results are shown in Figs. 2(*a*), (*b*), (*c*) and (*d*). The kinks in the curves, comparable to that in Fig. 1 were caused by pick-up of the local Band III television signal (Channel 9). Positive identification was obtained by switching off the wanted-signal carrier and the interfering-signal modulation when slight adjustment of the receiver tuning or the interfering-signal carrier frequency enabled the television sound channel to be heard clearly.

5. TESTS WITH A BROADCAST-STANDARD FREQUENCY-MODULATED INTERFERING SIGNAL

The four receivers that had been used for the tests described in Section 4 were also tested for their susceptibility to interference from a broadcast-standard signal and the results compared with similar tests made on six receivers, costing from £25 upwards, that had been made in 1967. One receiver (Receiver D) was used in both series of tests and the results were compared at six different offset frequencies. The agreement is as close as could be expected from a domestic receiver which is not specially designed to give long-term stability. For these tests the wanted signal was modulated by speech and the interfering signal by light music. Both channels had normal broadcast-standard pre-emphasis and deviation. As the level of the interfering signal was raised it first became perceptible by the appearance of a background of the interfering modulation.

The results for the four receivers are included in Fig. 2 and are compared with each other and with the results of the 1967 tests in Fig. 3. It is clear from the latter that the cheaper receivers have worse interference-rejection characteristics than the more expensive ones tested previously.

Figs. 2 and 3 also include the CCIR curve^2 of the 'necessary protection ratio' for reception under conditions of continuous interference from other broadcast transmissions. It is clear that if the interference were at the level indicated by this curve it would, for most values of Δf, be above the 'just perceptible' level for the four receivers tested, but no assessment was made of the grade of interference that would be caused.

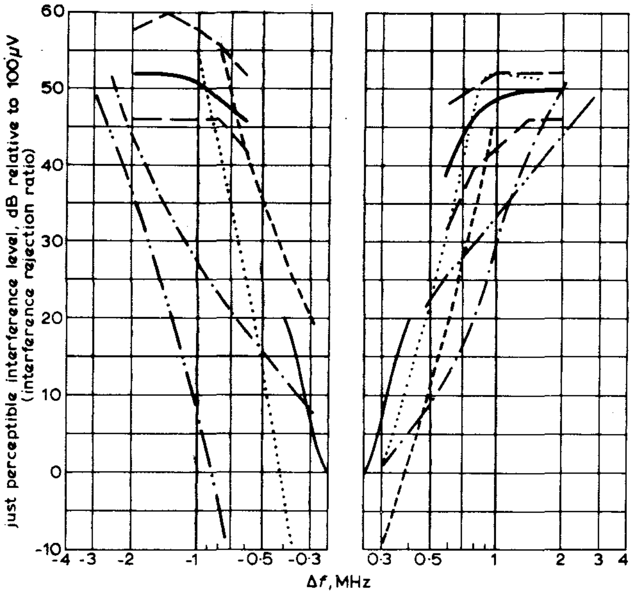


Fig. 3 - Interference rejection ratio; wide-band f.m. interfering signal. Comparison between receivers

——— · ——— Receiver A
· · · · · · · · · · · · · Receiver B
——— · · ——— Receiver C
— — — — — — — Receiver D
} October 1968

——————— CCIR 'Necessary Protection'
——— ———
——————
——— ———
} Range of values, omitting best and worst, for receivers costing £25 or more, April 1967.

6. CONCLUSIONS

All the measurements made in these tests concern interference to monophonic broadcasting. No measurements or deductions are made that concern stereophonic transmissions. It is apparent that few receivers can tolerate an interfering signal equivalent to more than 50 mV at the receiver input, even at the largest frequency spacing examined. Therefore the siting of a mobile base transmitter in a residential area is likely to give rise to complaints from its immediate neighbourhood.

The results of the tests show that if narrow-band f.m. is used in the mobile communication channel it gives less interference with broadcast reception than when a.m. is used; generally the improvement in the interference-suppression ratio is approximately 20 dB, provided that the interfering signal is below the overload level discussed in the last paragraph of Section 3.1, with little difference between the results for ± 5 kHz and ± 2·5 kHz deviation. The anomalous results for Receiver C are believed to be related to its poor tuning characteristic which is consistent with a discrepancy between the centre frequency of the discriminator circuit and the peak frequency of the i.f., a defect that was not apparent during the initial tests with a.m. interference but was found two weeks later when the other tests were made.

It was found that the cheaper receivers tended to have the poorer characteristics and could well be unsuitable for use in those areas where other services operate on channels within two or three megahertz of the broadcast channel. A subsidiary defect in the cheaper receivers is that the tuning drives are less satisfactory mechanically than those of better receivers, and the susceptibility to interference is found to be very dependent on accurate tuning to the wanted signal, especially when the frequency separation between the wanted and interfering carriers is less than 0·5 MHz. The results reported here are for tests in which the receivers were tuned accurately in the absence of any interfering signal.

7. RECOMMENDATIONS

The essential cause of difficulty is that receivers may be required to select a wanted signal from a broadcast transmitter in the presence of an appreciably stronger interfering signal from one of the transmitters – particularly the base station – of a mobile service. This calls for a higher standard of selectivity and freedom from overloading effects than would be required by the broadcast service alone. It would clearly be very advantageous if all frequency assignments to mobile services close to the f.m. broadcast band could be restricted to stations using narrow-band f.m. Furthermore, future assignments should take account of existing services to ensure that the frequency separation between mobile and broadcast channels in the same area is as large as possible and preferably not less than 0·5 MHz. As regards receiver performance, it would appear to be impractical to take the view either that all receivers should be made with good rejection or that planning of a broadcast system should ensure freedom from interference for all types of receiver. Under these circumstances it is important for the public to be informed, preferably by local dealers, that the cheaper receivers may not be satisfactory in proximity to transmitters of mobile services. Also, there should be available to the public receivers of reasonably good selectivity on which satisfactory planning may be based.

When interference is found the listener should check the tuning of his receiver and take advantage of any directivity that the aerial system may have. Re-positioning the receiver within the room may be beneficial because reflections from immediate surroundings can give some directivity. An important result, discussed in Section 3.1, is that a higher ratio of interfering to wanted field strength can be tolerated at lower signal levels. This shows that the listener should also try the effect of partially retracting the aerial so as to reduce the input levels of both the wanted and interfering signals.

8. REFERENCES

1. General Post Office. Performance Specification W6771, Private Land Mobile Radio Services, H.M.S.O. 1968.

2. CCIR Documents of the XIth Plenary Assembly, Recommendation 412, Vol. V, p.30, Oslo 1966.

APPENDIX

Receiver	Type*	Approximate Price
A	Pocket	£9 10s. 0d.
B	Standard Portable/Car	£20 0s. 0d.
C	Pocket	£12 0s. 0d.
D	Standard Portable	£26 0s. 0d. in 1966
E	Pocket	£8 10s. 0d.
F	Standard Portable	£17 0s. 0d.
G	Standard Portable	£72 0s. 0d. in 1964
H	Standard Portable/Car	£30 0s. 0d.
I	Pocket	£17 0s. 0d.

*A 'Pocket' size receiver is taken here as being smaller than 150 x 100 x 50 mm.

A 'Standard Portable/Car' receiver is taken as being one of Standard Portable size which is fitted with a car-radio input socket.

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Printed by BBC Research Department, Kingswood Warren, Tadworth, Surrey